

CLAIMS

1. A method of receiving data in a multiple-input multiple-output (MIMO) communication system, comprising:

obtaining, from a plurality of receive antennas at a receiving entity, a plurality of received symbol streams for a plurality of data symbol streams sent by a plurality of transmitting entities, one data symbol stream for each transmitting entity, wherein the data symbol stream for each transmitting entity is spatially processed with a steering vector for the transmitting entity and sent from a plurality of transmit antennas at the transmitting entity; and

processing the plurality of received symbol streams in accordance with a receiver spatial processing technique to obtain a plurality of recovered data symbol streams, which are estimates of the plurality of data symbol streams.

2. The method of claim 1, wherein the receiver spatial processing technique is a channel correlation matrix inversion (CCMI) technique or a minimum mean square error (MMSE) technique.

3. The method of claim 1, wherein the receiver spatial processing technique is a successive interference cancellation (SIC) technique.

4. The method of claim 1, wherein the steering vector for each transmitting entity is derived by

decomposing a channel response matrix for the transmitting entity to obtain a plurality of eigenvectors and a plurality of singular values, and

forming the steering vector for the transmitting entity based on an eigenvector corresponding to a largest singular value among the plurality of singular values.

5. The method of claim 4, wherein the steering vector for each transmitting entity is equal to the eigenvector corresponding to the largest singular value.

6. The method of claim 4, wherein the steering vector for each transmitting entity contains a plurality of elements having same magnitude and phases equal to

phases of a plurality of elements of the eigenvector corresponding to the largest singular value.

7. The method of claim 1, further comprising:

evaluating each of a plurality of sets of transmitting entities for possible transmission based on a metric and steering vectors for the transmitting entities in the set; and

selecting a set of transmitting entities with a highest metric value for transmission.

8. An apparatus at a receiving entity in a multiple-input multiple-output (MIMO) communication system, comprising:

a plurality of receiver units operative to obtain from a plurality of receive antennas a plurality of received symbol streams for a plurality of data symbol streams sent by a plurality of transmitting entities, one data symbol stream for each transmitting entity, wherein the data symbol stream for each transmitting entity is spatially processed with a steering vector for the transmitting entity and sent from a plurality of transmit antennas at the transmitting entity; and

a receive spatial processor operative to process the plurality of received symbol streams in accordance with a receiver spatial processing technique to obtain a plurality of recovered data symbol streams, which are estimates of the plurality of data symbol streams.

9. The apparatus of claim 8, wherein the receiver spatial processing technique is a channel correlation matrix inversion (CCMI) technique or a minimum mean square error (MMSE) technique.

10. The apparatus of claim 8, wherein the steering vector for each transmitting entity is derived by

decomposing a channel response matrix for the transmitting entity to obtain a plurality of eigenvectors and a plurality of singular values, and

forming the steering vector for the transmitting entity based on an eigenvector corresponding to a largest singular value among the plurality of singular values.

11. An apparatus at a receiving entity in a multiple-input multiple-output (MIMO) communication system, comprising:

means for obtaining from a plurality of receive antennas a plurality of received symbol streams for a plurality of data symbol streams sent by a plurality of transmitting entities, one data symbol stream for each transmitting entity, wherein the data symbol stream for each transmitting entity is spatially processed with a steering vector for the transmitting entity and sent from a plurality of transmit antennas at the transmitting entity; and

means for processing the plurality of received symbol streams in accordance with a receiver spatial processing technique to obtain a plurality of recovered data symbol streams, which are estimates of the plurality of data symbol streams.

12. The apparatus of claim 11, wherein the receiver spatial processing technique is a channel correlation matrix inversion (CCMI) technique or a minimum mean square error (MMSE) technique.

13. The apparatus of claim 11, wherein the steering vector for each transmitting entity is derived by

decomposing a channel response matrix for the transmitting entity to obtain a plurality of eigenvectors and a plurality of singular values, and

forming the steering vector for the transmitting entity based on an eigenvector corresponding to a largest singular value among the plurality of singular values.

14. A method of receiving data in a multiple-input multiple-output (MIMO) communication system, comprising:

obtaining, from a plurality of receive antennas at a receiving entity, a plurality of received symbol streams for a plurality of data symbol streams sent by a plurality of transmitting entities, one data symbol stream for each transmitting entity, wherein the data symbol stream for each transmitting entity is spatially processed with a steering vector derived independently for the transmitting entity and is sent from a plurality of transmit antennas at the transmitting entity, and wherein the plurality of data symbol streams are transmitted simultaneously by the plurality of transmitting entities; and

processing the plurality of received symbol streams in accordance with a receiver spatial processing technique to obtain a plurality of recovered data symbol streams, which are estimates of the plurality of data symbol streams.

15. The method of claim 14, wherein the steering vector for each transmitting entity is derived based on a channel estimate for a wireless channel for the transmitting entity.

16. An apparatus at a receiving entity in a multiple-input multiple-output (MIMO) communication system, comprising:

a plurality of receiver units operative to obtain from a plurality of receive antennas a plurality of received symbol streams for a plurality of data symbol streams sent by a plurality of transmitting entities, one data symbol stream for each transmitting entity, wherein the data symbol stream for each transmitting entity is spatially processed with a steering vector derived independently for the transmitting entity and is sent from a plurality of transmit antennas at the transmitting entity, and wherein the plurality of data symbol streams are transmitted simultaneously by the plurality of transmitting entities; and

a receive spatial processor operative to process the plurality of received symbol streams in accordance with a receiver spatial processing technique to obtain a plurality of recovered data symbol streams, which are estimates of the plurality of data symbol streams.

17. A method of transmitting data from a transmitting entity in a multiple-input multiple-output (MIMO) communication system, comprising:

obtaining a plurality of steering vectors for a plurality of receiving entities, one steering vector for each receiving entity, wherein the steering vector for each receiving entity is derived based on a channel response matrix indicative of a response of a MIMO channel between the transmitting entity and the receiving entity; and

performing spatial processing on a plurality of data symbol streams with the plurality of steering vectors to obtain a plurality of transmit symbol streams for transmission from a plurality of transmit antennas at the transmitting entity to the plurality of receiving entities.

18. The method of claim 17, wherein the steering vector for each receiving entity is derived by

decomposing a channel response matrix for the receiving entity to obtain a plurality of eigenvectors and a plurality of singular values, and

forming the steering vector for the receiving entity based on an eigenvector corresponding to a largest singular value among the plurality of singular values.

19. The method of claim 17, further comprising:

processing a plurality of data streams in accordance with Code Division Multiple Access (CDMA) to obtain the plurality of data symbol streams, wherein each data symbol stream is sent on a respective code channel and spectrally spread with a pseudo-random number (PN) sequence.

20. The method of claim 17, further comprising:

processing a plurality of data streams in accordance with Orthogonal Frequency Division Multiplexing (OFDM) to obtain the plurality of data symbol streams, wherein each data symbol stream is sent on a respective set of subbands.

21. An apparatus at a transmitting entity in a multiple-input multiple-output (MIMO) communication system, comprising:

a controller operative to obtain a plurality of steering vectors for a plurality of receiving entities, one steering vector for each receiving entity, wherein the steering vector for each receiving entity is derived based on a channel response matrix indicative of a response of a MIMO channel between the transmitting entity and the receiving entity; and

a transmit spatial processor operative to perform spatial processing on a plurality of data symbol streams with the plurality of steering vectors to obtain a plurality of transmit symbol streams for transmission from a plurality of transmit antennas at the transmitting entity to the plurality of receiving entities.

22. The apparatus of claim 21, wherein the controller is operative to decompose a channel response matrix for each receiving entity to obtain a plurality of

eigenvectors and a plurality of singular values and to form the steering vector for the receiving entity based on an eigenvector corresponding to a largest singular value among the plurality of singular values.

23. An apparatus at a transmitting entity in a multiple-input multiple-output (MIMO) communication system, comprising:

means for obtaining a plurality of steering vectors for a plurality of receiving entities, one steering vector for each receiving entity, wherein the steering vector for each receiving entity is derived based on a channel response matrix indicative of a response of a MIMO channel between the transmitting entity and the receiving entity; and

means for performing spatial processing on a plurality of data symbol streams with the plurality of steering vectors to obtain a plurality of transmit symbol streams for transmission from a plurality of transmit antennas at the transmitting entity to the plurality of receiving entities.

24. The apparatus of claim 23, further comprising:

means for decomposing a channel response matrix for each receiving entity to obtain a plurality of eigenvectors and a plurality of singular values, and

means for forming the steering vector for the receiving entity based on an eigenvector corresponding to a largest singular value among the plurality of singular values.

25. A method of scheduling user terminals for transmission in a multiple-input multiple-output (MIMO) communication system, comprising:

selecting a set of user terminals from among a plurality of user terminals;

forming an effective channel response matrix for the set based on effective channel response vectors for the user terminals in the set, wherein the effective channel response vector for each user terminal is obtained based on a steering vector and a channel response matrix for the user terminal, the steering vector being used by the user terminal for transmit spatial processing;

deriving a value for a metric for the set based on the effective channel response matrix for the set;

repeating the selecting, forming, and deriving for each of a plurality of sets of user terminals to obtain a plurality of metric values for the plurality of sets; and
scheduling a set of user terminals with a highest metric value for transmission.

26. The method of claim 25, wherein the metric is overall throughput and the set of user terminals with highest overall throughput is scheduled for transmission.

27. The method of claim 26, wherein the deriving a value for a metric for the set includes

computing a signal-to-noise-and-interference ratio (SNR) for each user terminal in the set based on the effective channel response matrix for the set and a receiver spatial processing technique,

determining a throughput for each user terminal in the set based on the SNR for the user terminal, and

accumulating throughputs for the user terminals in the set to obtain the overall throughput for the set.

28. The method of claim 27, wherein the throughput for each user terminal is determined based on a set of rates supported by the system and a set of required SNRs for the set of rates.

29. The method of claim 25, wherein the steering vector for each user terminal is derived based on the channel response matrix for the user terminal.

30. The method of claim 29, wherein the steering vector for each user terminal is derived by

decomposing the channel response matrix for the user terminal to obtain a plurality of eigenvectors and a plurality of singular values, one eigenvector for each singular value, and

forming the steering vector for the user terminal based on an eigenvector corresponding to a largest singular value among the plurality of singular values.

31. The method of claim 25, wherein steering vectors for the user terminals in each set are obtained based on channel response matrices for the user terminals in the set.

32. An apparatus in a multiple-input multiple-output (MIMO) communication system, comprising:

- a user selector operative to form a plurality of sets of user terminals from among a plurality of user terminals;

- an evaluation unit operative, for each of the plurality of sets, to

- form an effective channel response matrix for the set based on effective channel response vectors for the user terminals in the set, wherein the effective channel response vector for each user terminal is obtained based on a steering vector and a channel response matrix for the user terminal, the steering vector being used by the user terminal for transmit spatial processing, and

- derive a value for a metric for the set based on the effective channel response matrix for the set; and

- a scheduler operative to schedule a set of user terminals, from among the plurality of sets of user terminals, with a highest metric value for transmission.

33. The apparatus of claim 32, wherein the evaluation unit includes

- a matrix computation unit operative to compute a signal-to-noise-and-interference ratio (SNR) for each user terminal in each set based on the effective channel response matrix for the set and a receiver spatial processing technique, and

- a rate selector operative to determine a throughput for each user terminal in each set based on the SNR of the user terminal and to accumulate throughputs for the user terminals in each set to obtain an overall throughput for the set, wherein the metric is overall throughput and the set of user terminals with highest overall throughput is scheduled for transmission.

34. An apparatus in a multiple-input multiple-output (MIMO) communication system, comprising:

- means for selecting a set of user terminals from among a plurality of user terminals;

means for forming an effective channel response matrix for the set based on effective channel response vectors for the user terminals in the set, wherein the effective channel response vector for each user terminal is obtained based on a steering vector and a channel response matrix for the user terminal, the steering vector being used by the user terminal for transmit spatial processing;

means for deriving a value for a metric for the set based on the effective channel response matrix for the set;

means for repeating the selecting, forming, and deriving for each of a plurality of sets of user terminals to obtain a plurality of metric values for the plurality of sets; and

means for scheduling a set of user terminals with a highest metric value for transmission.

35. The apparatus of claim 34, further comprising:

means for computing a signal-to-noise-and-interference ratio (SNR) for each user terminal in the set based on the effective channel response matrix for the set and a receiver spatial processing technique;

means for determining a throughput for each user terminal in the set based on the SNR for the user terminal; and

means for accumulating throughputs for the user terminals in the set to obtain an overall throughput for the set, wherein the metric is overall throughput and the set of user terminals with highest overall throughput is scheduled for transmission.

36. A processor readable media for storing instructions operable to:

select a set of user terminals from among a plurality of user terminals in a multiple-input multiple-output (MIMO) communication system;

form an effective channel response matrix for the set based on effective channel response vectors for the user terminals in the set, wherein the effective channel response vector for each user terminal is obtained based on a steering vector and a channel response matrix for the user terminal, the steering vector being used by the user terminal for transmit spatial processing;

derive a value for a metric for the set based on the effective channel response matrix for the set;

repeat the selecting, forming, and deriving for each of a plurality of sets of user terminals to obtain a plurality of metric values for the plurality of sets; and
schedule a set of user terminals with a highest metric value for transmission.

37. A method of deriving steering vector for data transmission in a multiple-input multiple-output (MIMO) communication system, comprising:

obtaining a channel response matrix indicative of a response of a MIMO channel between a transmitting entity and a receiving entity in the MIMO system;

decomposing the channel response matrix to obtain a plurality of eigenvectors and a plurality of singular values, one eigenvector for each singular value; and

deriving the steering vector for the transmitting entity based on an eigenvector corresponding to a largest singular value among the plurality of singular values, and

wherein a plurality of steering vectors are derived for a plurality of transmitting entities and used for spatial processing by the plurality of transmitting entities to concurrently transmit a plurality of data symbol streams to the receiving entity.

38. The method of claim 37, wherein the steering vector for each transmitting entity is the eigenvector corresponding to the largest singular value.

39. The method of claim 37, wherein the steering vector for each transmitting entity contains a plurality of elements having same magnitude and phases equal to phases of a plurality of elements of the eigenvector corresponding to the largest singular value.

40. An apparatus in a multiple-input multiple-output (MIMO) communication system, comprising:

a channel estimator operative to obtain a channel response matrix indicative of a response of a MIMO channel between a transmitting entity and a receiving entity in the MIMO system; and

a controller operative to decompose the channel response matrix to obtain a plurality of eigenvectors and a plurality of singular values, one eigenvector for each singular value and to derive the steering vector for the transmitting entity based on an

eigenvector corresponding to a largest singular value among the plurality of singular values, and

wherein a plurality of steering vectors are derived for a plurality of transmitting entities and used for spatial processing by the plurality of transmitting entities to concurrently transmit a plurality of data symbol streams to the receiving entity.

41. An apparatus in a multiple-input multiple-output (MIMO) communication system, comprising:

means for obtaining a channel response matrix indicative of a response of a MIMO channel between a transmitting entity and a receiving entity in the MIMO system;

means for decomposing the channel response matrix to obtain a plurality of eigenvectors and a plurality of singular values, one eigenvector for each singular value; and

means for deriving the steering vector for the transmitting entity based on an eigenvector corresponding to a largest singular value among the plurality of singular values, and

wherein a plurality of steering vectors are derived for a plurality of transmitting entities and used for spatial processing by the plurality of transmitting entities to concurrently transmit a plurality of data symbol streams to the receiving entity.

42. A method of transmitting data from a transmitting entity in a multiple-input multiple-output (MIMO) communication system, comprising:

obtaining a steering vector for the transmitting entity, wherein the steering vector is derived based on a channel response matrix indicative of a response of a MIMO channel between the transmitting entity and a receiving entity in the MIMO system; and

performing spatial processing on a data symbol stream with the steering vector to obtain a plurality of transmit symbol streams for transmission from a plurality of antennas at the transmitting entity to the receiving entity, and

wherein a plurality of steering vectors are obtained and used for spatial processing by a plurality of transmitting entities, including the transmitting entity, to concurrently transmit a plurality of data symbol streams to the receiving entity.

43. The method of claim 42, further comprising:

processing a data stream in accordance with Code Division Multiple Access (CDMA) to obtain the data symbol stream, wherein the data symbol stream is sent on a code channel and spectrally spread with a pseudo-random number (PN) sequence.

44. The method of claim 42, further comprising:

processing a data stream in accordance with Orthogonal Frequency Division Multiplexing (OFDM) to obtain the data symbol stream, wherein the data symbol stream is sent on an assigned set of subbands.

45. The method of claim 42, further comprising:

receiving a pilot from the receiving entity;
processing the received pilot to obtain the channel response matrix;
decomposing the channel response matrix to obtain a plurality of eigenvectors and a plurality of singular values, one eigenvector for each singular value; and
deriving the steering vector based on an eigenvector corresponding to a largest singular value among the plurality of singular values.

46. The method of claim 42, further comprising:

sending a pilot to the receiving entity; and
receiving the steering vector from the receiving entity.

47. An apparatus at a transmitting entity in a multiple-input multiple-output (MIMO) communication system, comprising:

a controller operative to obtain a steering vector for the transmitting entity, wherein the steering vector is derived based on a channel response matrix indicative of a response of a MIMO channel between the transmitting entity and a receiving entity in the MIMO system; and

a transmit spatial processor operative to perform spatial processing on a data symbol stream with the steering vector to obtain a plurality of transmit symbol streams for transmission from a plurality of antennas at the transmitting entity to the receiving entity, and

wherein a plurality of steering vectors are obtained and used for spatial processing by a plurality of transmitting entities, including the transmitting entity, to concurrently transmit a plurality of data symbol streams to the receiving entity.

48. The apparatus of claim 47, further comprising:

a channel estimator operative to receive and process a pilot from the receiving entity to obtain the channel response matrix, and

wherein the controller is further operative to decompose the channel response matrix to obtain a plurality of eigenvectors and a plurality of singular values, one eigenvector for each singular value, and to derive the steering vector based on an eigenvector corresponding to a largest singular value among the plurality of singular values.

49. The apparatus of claim 47, further comprising:

a transmit data processor operative to process a data stream in accordance with Code Division Multiple Access (CDMA) to obtain the data symbol stream, wherein the data symbol stream is sent on a code channel and spectrally spread with a pseudo-random number (PN) sequence.

50. The apparatus of claim 47, further comprising:

a transmit data processor operative to process a data stream in accordance with Orthogonal Frequency Division Multiplexing (OFDM) to obtain the data symbol stream, wherein the data symbol stream is sent on an assigned set of subbands.

51. An apparatus at a transmitting entity in a multiple-input multiple-output (MIMO) communication system, comprising:

means for obtaining a steering vector for the transmitting entity, wherein the steering vector is derived based on a channel response matrix indicative of a response of a MIMO channel between the transmitting entity and a receiving entity in the MIMO system; and

means for performing spatial processing on a data symbol stream with the steering vector to obtain a plurality of transmit symbol streams for transmission from a plurality of antennas at the transmitting entity to the receiving entity, and

wherein a plurality of steering vectors are obtained and used for spatial processing by a plurality of transmitting entities, including the transmitting entity, to concurrently transmit a plurality of data symbol streams to the receiving entity.

52. The apparatus of claim 51, further comprising:
means for receiving a pilot from the receiving entity;
means for processing the received pilot to obtain the channel response matrix;
means for decomposing the channel response matrix to obtain a plurality of eigenvectors and a plurality of singular values, one eigenvector for each singular value;
and
means for deriving the steering vector based on an eigenvector corresponding to a largest singular value among the plurality of singular values.